REINFORCING METHOD WITH OVERLAID ULTRA-HIGH-EARLY-STRENGTH CONCRETES

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ABSTRACT

As measures for deck slab degradation and upsizing of vehicles, the slab reinforcing method with overlaid concretes has been mainly applied. However, some of slabs were damaged in a period of several years after the completion of slab reinforcement work with overlaid concretes, thus repeatedly causing damage to pavements such as potholes. It is supposed that the said damage resulted from a decrease in strength of bonding between the existing slabs and overlaid concretes due to the insufficient compaction of the overlaid concretes or insufficient mixing of steel fiber. Consequently, in order to reinforce slabs with overlaid concretes by a method that ensures workability and provides a high level of quality and durability and also low costs, the authors have been carrying out studies on construction methods with ultra-high-early-strength concretes in place of conventional methods with ultra-rapid-hardening SF (steel fiber) reinforced concretes since fiscal 2006. As a result of test construction, it turned out that enhancement of workability was essential to the improvement of

bonding strength, boundary delamination ratio, and non-filling ratio. The test construction got the result that the reinforcing method with ultra-high-early-strength concretes was superior in constructability, economic efficiency, and safety compared to the conventional methods with ultra-rapid-hardening SF concretes.

1. INTRODUCTION

The section between Kyoto Higashi (East) IC and Suita JCT of the Meishin Expressway administrated by Ibaraki Operation Office of West Nippon Expressway Co., Ltd. is a heavy-trafficked highway with daily traffic of approx. 100,000 vehicles and playing a vital role as an infrastructure road for industries, sightseeing, and daily lives of local residents. This section commenced its service in July 1963, and approx. 45 years have elapsed since then. Until now, the reinforcing method with overlaid concretes[1] has been applied as measures for deck slab degradation and upsizing of vehicles to implement reinforcement work. For the section between Kyoto Higashi IC and Kyoto Minami (South) IC in which this reinforcement work is implemented, the slab repair work was implemented by the five-year plan from 2006 after the completion of the bypass between Seta Higashi JCT and Ooyamazaki JCT of Keiji Bypass, and the construction for the fourth year was completed this year.(Fig.1)

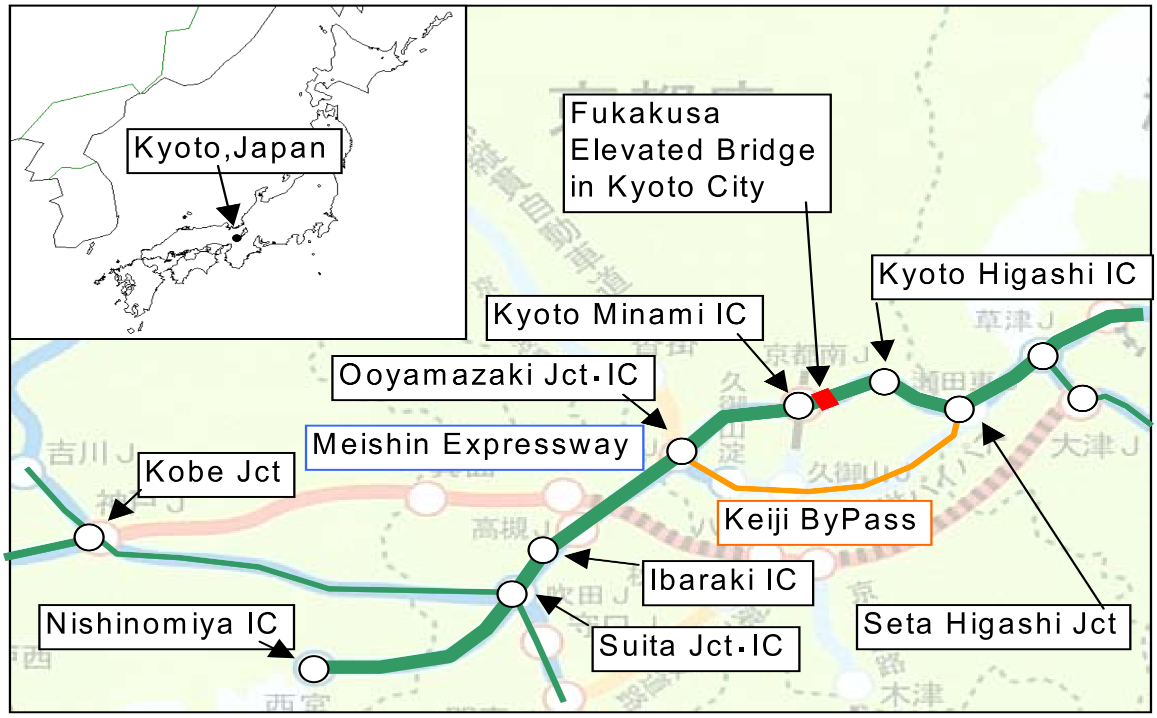

Fig.1 Map

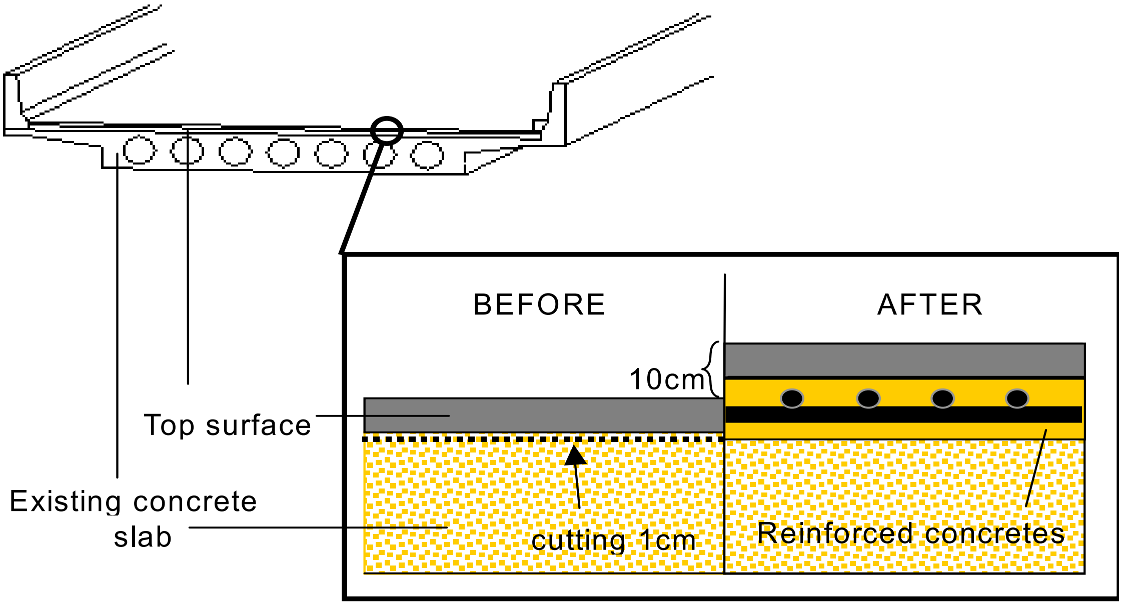

Fig.2 Slab reinforcing method with overlaid concretes

The slab reinforcing method with overlaid concretes is a construction method to reinforce slabs mainly for punching shear as measure against damage of RC steel bridge decks by cutting the top surface of the existing concrete slab, and then shot-blasting the cut surface and casting ultra-rapid-hardening steel fiber reinforced concretes (hereinafter referred to as the "ultra-rapid-hardening SFRC) to integrate new and old concretes and overlay them. On the other hand, the superstructure reinforcing method with overlaid reinforced concretes commonly used for RC and PC continuous bridges is a construction method to arrange superstructure reinforcements in overlaid concrete and enhance the flexural capacity of main girder and main slab of the intermediate fulcrum point and the cantilever slab. When reinforcement work is implemented on routes in service by applying these construction methods, traffic on one lane has been controlled. Consequently, mixing of concretes has been designed with the objective of shortening work periods so that the ultra-rapid-hardening SFRC that is most likely to present early strength can be supplied in a low slump from a mobile site plant without causing material segregation so as to ensure strength at a specified age. In addition, the methods made it possible to evenly combine old and new concretes by cutting the existing slabs by approx. 1 cm and shot-blasting them in order to eliminate degraded portions, tack coats, etc. from concretes.

However, regarding to the reinforcing method with overlaid concretes, the following three issues, including construction methods, are considered questionable.

Firstly, this method caused damage to some of slabs in a period of eight to ten years after the completion of slab reinforcement work with overlaid concretes that was implemented under the control

of Ibaraki Administration Office, thus repeatedly causing damage to pavements such as potholes. Portions repeatedly causing such damage have been fixed up by casting the ultra-rapid-hardening SFRC up to the paved surface. The following section shows the specific areas of slabs that presented re-degradation.

(1) Areas constructed by human power in the vicinity of expansion device, etc.

(2) Ends of boundary between the primary construction and the secondary construction implemented by lane control

As to the properties of the ultra-rapid-hardening SFRC, it mixed as low slump to the extent that it caused no material segregation during transport or compaction. Since the areas listed above could not be compacted with a large-sized finisher, they could not be compacted with manual vibrators, and thereby caused insufficient compaction followed by a decrease in bonding strength between existing and new slabs, allowing water invasion to result in damaged slabs.

Secondly, the method needs to spread, compact, and finish overlaid ultra-rapid-hardening SFRC using a high amount of vibrational energy, causing noises and vibrations under bridges. Regarding Fukakusa Elevated Bridge and Takeda Elevated Bridge, since these bridges are located in an urban area adjacent to and dense with houses around them, thorough consideration should be given to construction environments to control noises and vibrations wherever possible.

Lastly, the ultra-rapid-hardening SFRC has short handling time, a site plant for the ultra-rapid-hardening SFRC must be installed to maintain its properties within the specified range, making it costly compared ready-mixed concrete .

Regarding the construction methods and environments, we verified the effectiveness of ultra-high-early-strength concretes[2] (hereinafter referred to as the “UHRC”) that can be shipped from ready-mixed concrete plants in place of the conventional ultra-rapid-hardening SFRC that are mixed at construction site. The following section shows major items we verified.

(1) Ensuring of strength of bonding between existing and new slab concretes

(2) Reduction of vibrations and noises caused during construction

This paper is intended to make a report on the results of verification of practical construction on Fukakusa Elevated Bridge for the items shown above.

2. PROPERTIES REQUIRED FOR UH RC

The following section shows properties we required for the ultra-high-early-strength RC.

(1) Compressive strength of not less than 24N/mm^2 design strength must be demonstrated at the age of 24 hours.

(2) Concrete slump and air content must be maintained at a level of 12±2.5 cm and 4.5±1.5%

respectively while approx. one hour after the concrete is mixed.

(3) Concrete slump must be maintained at a level of 8 cm after a lapse of approx. two hour since the concrete is mixed.

3. IMPLEMENTATION OF CONSTRUCTION ON FUKAKUSA ELEVATED BRIDGE

3.1 Outline of Construction Method

The range of the construction implemented in 2007 covered a section of 228 m in length on the Fukakusa Elevated Bridge (of 885 m in bridge length) on the up lane of the expressway that was a two-lane section with a transverse structure having a shoulder of 1.654 m wide on the left side, cruising and passing lanes of 3.600 m wide, and a shoulder of 0.7 m wide on the median side (see Fig. 3). Since this construction started with overlaying new concrete directly on the existing concrete slabs on the passing lane side, we delaminated the pavement using a road surface grinder. Consequently, we cut the existing slabs by approximately 1 cm in order to remove deteriorated concretes and tack coats, and then shot-blasted the cut surface, followed by reinforcing the slabs with prefabricated superstructure, casting concrete slabs of 10 cm thick with the use of a concrete finisher, and finally implementing waterproofing and paving work . After that, we shifted the traffic control to the cruising lane to implement the construction on this lane in the same manner. With that, we completed all the construction work.

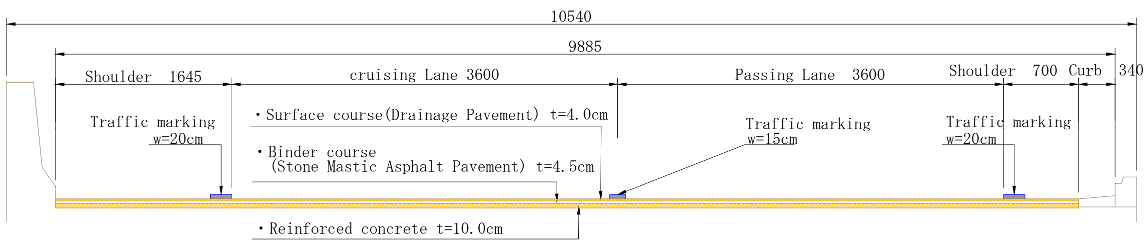

Fig.3 Fukakusa Elevated Bridge Cross Section

3.2 Review of Concrete Transporting, Spreading, Compacting, and Finishing Methods

Since concrete curing time for the construction of UHRC comes to 24 hours from 3 hours, we reviewed the organization and improvement of machines to increase the construction speed so that no delay in the construction schedule would be caused.

Our original plan was to transport UHRC up to the construction site using an agitator truck, pump the UHRC using a concrete pumping vehicle, and spreading, compacting, and finishing it using a simplified powered finisher.

However, we considered construction risks such as high potential for blocking piping due to the high viscosity of UHRC and the need to frequently disconnect piping, and thereby decided to use a tire shovel for transporting UHRC that was the same method as that used to cast ultra-rapid-hardening SFRC. Further, since the concrete slabs were reinforced with superstructure on the construction site, we transported UHRC by providing a temporary path on the concrete slabs and using a tire shovel of $0.4m^3$ class (see Photo 1). In addition, we had to load 0.35 m^3 of UHRC in the tire shovel in order to supply concrete corresponding to the running speed of the concrete finisher. For this purpose, we reinforced and increased the height of the bucket with steel plates to prevent UHRC from spilling during transportation even in cases where concrete slump is 12 cm (see Photo 2). Regarding the construction speed, since it depended on the concrete supply capacity of the tire shovel and thereby needed to be equivalent to that of the Jet Concrete, it was difficult to be improved.

For spreading, compaction, and finish of UHRC, we planned to use a simplified finisher. As a result of test construction, however, we could not meet a specified value for the bond strength. The reason is supposed that the vibration of the simplified finisher could not achieve uniform spreading of UHRC and obtain sufficient energy for compaction.

Under these circumstances, we spread UHRC using a large-sized finisher, compacted it using a working platform and five workers with the rod type vibrator (see Photo 3), and finished its surface using a simplified finisher towed by the large-sized finisher (see Photo 4). Consequently, we met the specified value for the bond strength and thereby decided to fix the rod type vibrator to each end of the large-sized finisher in order to ensure compaction at the end portions. Lastly, in order to prevent initial cracks and enhance bond strength to the waterproof layer, we used a hand trowel that mechanically torques the part contacting the concrete surface to finish it (see Photo 5).

3.3 Improvement of Construction Machines by Environmental Measures

In the past, when casting ultra-rapid-hardening SFRC, we have spread, compacted, and finished it by giving higher vibration energy to it with a large-sized finisher in order to ensure bond strength between old and new concretes. However, since this casting method produces intense noises and vibrations, we have implemented construction during the daytime in construction sections closed to residences.

Since we could not reduce the construction schedule by increasing construction speeds, we made studies on improvement of the large-size finisher to enable spreading UHRC during the night time on the previous day so that the construction schedule would become comparable with that for casting

Photo 1:
Discharging UHRC from the agitator truck to the tire shovel

Photo 2:
Transporting UHRC using the tire shovel

Photo 3:
Compacting UHRC using the rod type vibrator

Photo 4:
Finishing UHRC surface using the simplified finisher

Photo 5:
Finishing UHRC surface using the hand trowel

Photo 6:
Weight of rotator

ultra-rapid-hardening SFRC. We implemented test construction[3] to verify that reduction of noises and vibrations was enabled by changing mass of the weight mounting to the rotator that vibrates the float plate and mold plate of the large-sized concrete finisher (hereinafter referred to as the "weight" and described in thickness as shown in Fig. 4 (see Photo 6)) and inverter frequency. The test construction[3] verified that reduction of noises and vibrations would be enabled by reducing the vibration energy to a level at which the weight came to 9 mm and the frequency to 55Hz for reinforcing work with concrete

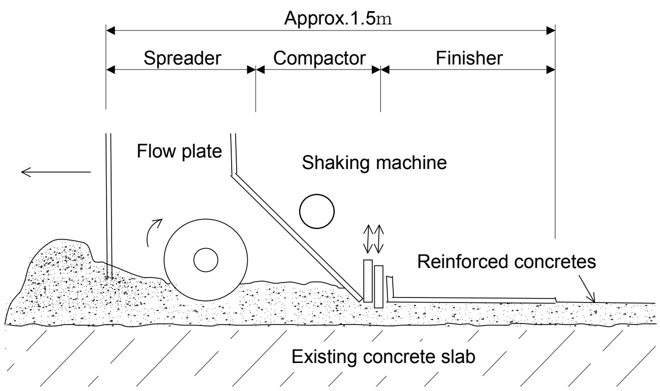

Fig.4 Large-sized finisher

cured for a period of 24 hours (the weight to 21 mm and the frequency to 55Hz for reinforcing work with ultra-rapid-hardening SFRC).

4. RESULTS OF TEST CONSTRUCTION

We cast concrete during the time zone from 20:00 hours to 6:00 hours next morning during which traffic volume got less in consideration of effects of traffic jams due to traffic control for the construction. As a result, time to transport concrete from the readily-mixed concrete plant to the construction sire came to 52 minutes at maximum, 20 minutes at minimum, and 30 minutes on average, thus making it possible to avoid traffic jams and complete the construction work approximately as planned (see Fig. 5).

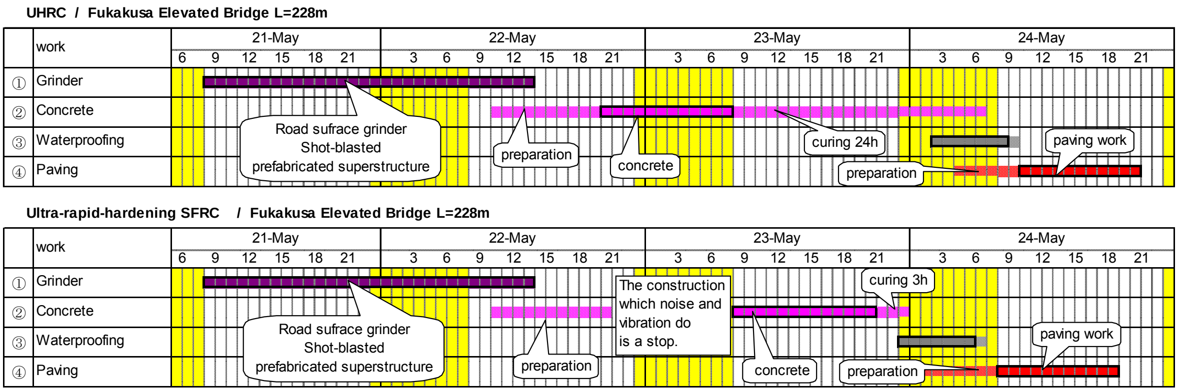

Fig.5 Work Schedule

5. QUALITY OF UHRC

Table 1 shows the mix proportion of concretes shipped, and Table 2 shows the results of quality control tests that were conducted when the concretes arrived at the construction site. All the test results achieved the target values of slump, air quantity, and compressive strength. In addition, it was not much, but the subsequent construction implemented on the cruising lane resulted in a higher level of skills and minor variations in the slump and air quantity compared to the first construction implemented on the passing lane.

Table 1 Mix proportion

Concretes	Gmax. (mm)	Slump (cm)	Air (%)	W/C (%)	s/a (%)	Unit Weight(kg/m^3)					
						W	C	Add	S	G	SF
Ultra-rapid-hardening SFRC	20	8? .5	—	39	56	167	428	—	966	764	100
UHRC		12? .5	4.5? .5	45	45	165	367	—	775	995	—

Table 2 Result of quality control test

	Slump(cm)					Air(%)					Compressive strength (N/mm^2)			
	n	Max	Min	Ave	σ	n	Max	Min	Ave	σ	18h	21h	24h	7Day
Target	12? .5cm					4.5? .5%					24N/mm2 (24hr)			
Primary (5/22)	7.0	14.0	10.0	11.8	1.5	3.0	5.2	4.0	4.6	0.5	24.2	26.9	27.5	48.2
Secondary(5/29)	11.0	14.0	12.0	13.2	0.6	3.0	5.2	5.0	5.1	0.1	24.4	26.9	27.7	47.8

During the first construction implemented on the passing lane, the second to fifth agitator trucks took longer waiting time on the site, i.e., approximately 60 minutes after shipment , thus resulting in a drop in the slump level. Consequently, before discharging concretes, we added admixture by 0.2 to 0.3% of the cement amount in these agitator trucks again and rotated at high speeds to restore the slump level and use the concretes. Since it was verified by the test construction that concretes with admixture added again met the bond strength, we implemented the same on the practical construction. During the construction implemented on the cruising lane, the first agitator truck took waiting time of approximately 90 minutes after shipment due to adjustment of the work schedule and caused a significant drop in the slump level of the 24-hour concrete, and thereby we disposed of concrete in the first agitator truck.

6. Noise and Vibration Investigation

In order to find out influence of the construction work on ambient environment, we made measurement of noises, vibrations, and low-frequency sounds on the ground.

In addition, since there was a section in which construction work with the use of the ultra-rapid-hardening SFRC was implemented during daytime on the following day of the construction work with the use of the UHRC implemented during nighttime, we made comparisons and evaluations of a variety of measurement.

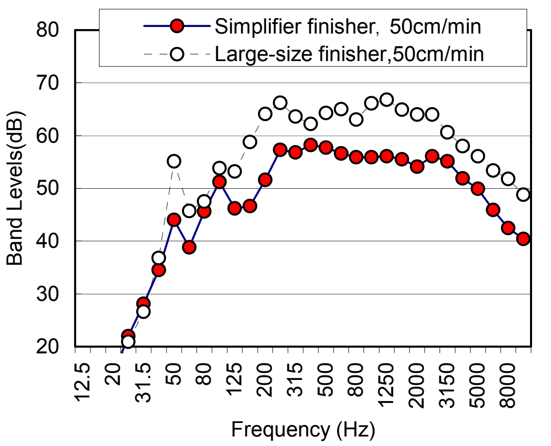

Fig.6 Frequency analysis on noise levels

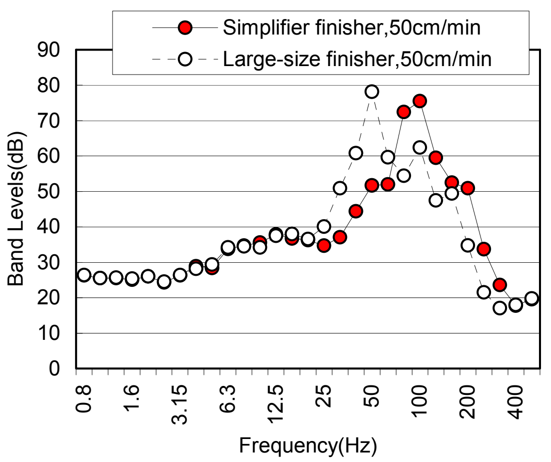

Fig.7 Frequency analysis on vibration levels

(1) Noise levels

The average level of noises including background noises at the time of construction was 74dB for the ultra-rapid-hardening SFRC used for construction implemented during daytime and 68dB for the UHRC used for construction implemented during nighttime. The environmental standards applicable to the relevant region provide that the noise levels during nighttime shall meet the ambient criterion of 65dB and the request limit of 70dB. The said average level does not meet the ambient criterion, but meet the

request limit. The normal noise level during nighttime in the relevant region is approx. 60 to 62dB.

(2) Vibration levels

Vibration levels are most affected in the vertical direction out of the three components and distributed in the range of 45 to 55dB. The amplitude of vibration in the vertical direction has no distinct differences depending on the types of concretes to be cast and is largely maintained at the same level. No ambient criteria for vibration levels are established. However, the request limit in the relevant region is 65dB during daytime and 60dB during nighttime, and the measurements meet the request limit.

7. CONCLUSION

For the bridge slab reinforcing work being implemented as the environment improvement project of Fukakusa Elevated Bridge of the Meishin Expressway, we used the UHRC that provides the given strength in a period of 24 hours besides the conventional ultra-rapid-hardening SFRC with the objective of reducing burden to the ambient environment and cutting costs.

For construction with the UHRC, we applied the reinforcing method with overlaid concretes that was considered difficult to apply to construction in urban areas to implement the construction during nighttime after implementing test construction beforehand and carrying out studies of the constructability and quality as well as influences of noises and vibrations on ambient environment. As a result, we could complete the construction reaching a high level of economic efficiency and constructability compared to the conventional method with ultra-rapid-hardening SFRC without receiving complaints from neighboring residents.

We, NEXCO-West (Nippon Expressway Co., Ltd.) are currently preparing the “Guidelines for Design and Construction of Reinforcing Method with Overlaid Ultra-high-early-strength Concretes”[3] in order to spread the results aforementioned. We hope this reinforcing method with overlaid concretes will be a guide for repair methods.

REFERENCES

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